VIP: *Vacuum Infusion Process*

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VIP is an acronym to describe a technology for closed molding of fiberglass reinforced plastics. The VIP concept is: to use vacuum pressure for pushing liquid resin into dry reinforcements that have been laid in a sealed mold. This mold can be a one sided hard shell with a vacuum bag, a two sided hard shell with a vacuum seal or and all around soft bag.

Any process that uses a lower-than-atmospheric pressure to drive resin into the mold cavity is VIP (Vacuum Infusion Molding).

Any system that uses higher-than-atmospheric pressure to drive the resin is RTM (Resin Transfer Molding).

Several acronyms describe the different methods to deliver and distribute the resin. A common goal of all systems is to get the resin to its final destination in the fastest and easiest way possible.

Fortunately, there's no magic involved in making this happen. VIP obeys Darcy's law, formulated by Henri D'Arcy, a French civil engineer, in 1856 while researching water flow through soil.

The filling time for a VIP part is determined by four elements:

- Viscosity of the resin,
- Porosity/permeability of the reinforcement,
- Applied pressure difference
- Flow distance

Lets look at these elements in more detail.

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Viscosity

Within one Bar or 14.7 psi as maximum working pressure of vacuum infusion, the practical higher limit for the resin viscosity is around 400 cps. Most large resin suppliers have infusion resins with a viscosity around 250 cps for ortho and iso polyesters, below 200 cps for vinylesters. Low viscosity blends, including DCPD can also offer a very cost-effective solution with good mechanical properties and

fatigue resistance. Epoxy resins, when formulated for low viscosity and sufficient exotherm control, can also be used. Very low viscosity can be achieved by heating up resins prior to mixing. Besides the low viscosity, the Thixotropic index of the resin is also important.

Porosity/Permeability

It is important that the resin can travel through the laminate at an even speed, i.e. meets the same level of porosity and permeability to keep the resin front even. There are two aspects to this: the void space between the fibers has to be big enough to let the resin flow through, and the size of the void has to be even. Straight fibers such as stitched fibers have better flow characteristics than woven rovings, which crimp at every fiber intersection. Random dispersed fibers such as continuous strand mat, provide a great deal of permeability, even after compression, and can aid the resin flow. Non-woven bulk materials and continuous strand mat are also facilitating flow through the laminate.

Pressure difference.

A full vacuum equals one atmosphere or 14.7 PSI. This is the maximum pressure difference that we can use in VIP, but it is sufficient to infuse even large structures in a short time, provided that we do not have too much vertical rise. The pressure gradually decreases as the height of the vertical infusion track increases. Full vacuum is a key ingredient in VIP. First, to achieve maximum infusion pressure. But also because the air that remains in the laminate when you apply only a partial vacuum poses risks for dry spots and inclusions.

Flow distance

One of the biggest issues in resin infusion is the modeling of the distance that the resin has to travel between infusion point and delivery point. When the resin travels through the vacuum-compressed fiber reinforcement, the cumulative resistance will gradually slow it down. Shortening the travel distance can be done by multiplying the infusion points, creating feed channel grids, adding a feeding layer, or any combination there off. The beauty of feeding layer delivery systems is that the resin can travel fast in the feeding layer over the entire laminate and migrate into the reinforcement from there, a distance of a mere few millimeters in most cases.

Resin front.

A fair part of the training for shopfloor crews is spent on feeder and vacuum line design and layout. They are the primary means to control the resin flow and fill rate. Size of the lines, distance, and breaks are different for every part. There is no "how to" handbook, and a lot rides on the experience of the crew, as well as on keeping good records, and extensive testing of complicated sections. In general terms, when the pressure in the vacuum cavity is even, and the reinforcements have an even porosity/permeability, a resin front will flow very evenly. Several software packages are available to model resin flow, but for the average boat building application it is sufficient in most cases to simulate the flow on a partial lay-up to predict flow pattern and fill time

Current infusion methods.

The three basic methods for resin delivery are:

- Surface medium
- Core channels
- Interlaminar medium

Surface medium systems

This technique allows very fast distribution of large quantities of resin, and provides good control over the flow front. Surface medium systems are very adaptable and can effectively be used for one-off or small series construction. The size and direction of the feeder lines can be adapted to a part or an area, and the medium can be selectively placed to control the resin front. Surface medium systems can be disposable, placed underneath a vacuum bag, or can have a reusable bag with the distribution medium and channels incorporated. The drawbacks of any disposable medium method are the amount of waste it generates and the manual placement of the medium for each part. The manual placement is eliminated by the reusable bag systems, but reusable bags are expensive and their handling requires a thorough knowledge of the process. The best known surface medium system is SCRIMPTM, which uses a knitted shade cloth as a distribution medium, with a grid of permeable feeder and vacuum lines connected to it.

Core Channels

Core channels or grooves are a simple, straightforward way to distribute resin in cored laminates. They can either be precut by the manufacturer, or be made on site. Number of channels, size and depth of the cuts and layout of larger feeder grooves are made according to part size and reinforcements. Core channel infusion is most effective on flat surfaces, and a very effective, waste-free way to infuse parts where the cosmetics are not critical. Because the channels are full of resin, they will shrink more than the surrounding foam and show a very defined print pattern. The resin in the core channels will add some weight to the part, but this can offset the cost of disposable supplies with other systems.

Recent developments in core channel technology make it possible to reduce the print issue to a minimum and limit the weight addition that the channels create.

Interlaminar medium

Interlaminar media originate in RTM, but are getting more use in VIP applications. They provide a flow path by incorporating a highly porous layer in the laminate, such as a continuous roving material or a non-woven breeder-like material. As the interlaminar feed layer is resin rich, the total fiber/resin ratio gains with this method are limited. But by spacing the high fiber volume layers to the outside of the laminates, the medium helps to increase the thickness and consequently the stiffness. A new development are laminates with a porous core composed of multi-axis fibers that act as spacers but have enough fibers in the Z-direction to absorb and transmit stresses. Recently, new weave styles with flow channels incorporated have been introduced and show great promise.

Getting started with VIP

What does it take to get into infusion? The equipment list to get started is rather short: a good vacuum pump (has to deliver sufficient cfm. at pressures over 27 Hg), an acoustic listening device, a thermometer, a few resin collectors, clamps, hoses, vacuum gauges and the usual vacuum bagging supplies. For a small test set up, the equipment budget will be less than a thousand dollars. The major cost for larger shops is a good fail-safe vacuum system with twin pumps, filter, reservoir and permanent vacuum lines throughout the shop.

The biggest cost associated with VIP conversion is the mold modifications and the overhaul of the plant lay-out to adapt it to the VIP process.

To learn the technology of VIP, one can go different ways: spend money on licenses and training or go experimenting in a corner of the shop. While the experimenting part may be very appealing to the individualistic nature of the fiberglass technician, it doesn't take long to spend a few thousand dollars on materials and labor, hoping to solve all the intricate details that make the difference between science and black magic in VIP. While VIP relies on the four principles of d'Arcy's law, it also requires a lot of attention to detail and an intricate knowledge of the process (which I usually define as the fifty-one tricks of infusion). Economically, it makes more sense to bite the bullet and call in an experienced "vipper". A VIP base-course is one week, but it takes two to four weeks to train the average fiberglass worker to a point where he has production-ready skills. Count on a training budget of 5 to 7,000 $. Depending on the chosen system, the technology can be open or may require licensing. A review of the most relevant patents is attached to this summary.

To VIP…

The bigger the size of the product, the more sense it makes to VIP: there is no other system available to apply the kind of mechanical pressure on big molds that can be achieved by using the 14.7 PSI delivered by the air pressure difference.

Furthermore, as laminates get thicker and more complicated, secondary bonding becomes more of an issue during large part construction. There's no secondary bonding in VIP. There are no voids in VIP laminates. Laminates are pre-compacted, then saturated with resin. All reinforcements are placed dry, can be aligned and adjusted without the worry of running out of time. There are no multiple bagging sessions, no core putties. VIP eliminates the manual application of large quantities of resin, and having to deal with large, wet and slippery surfaces. There are no massive styrene emissions during the large lay ups. There is no need for the workers to suit up as for a venture in outer space. No sticky floors, rollers, gloves or cleaning solvents. Net resin savings are usually in the order of 30 to 40%.

Stringers, inserts, backing plates and other structural reinforcements etc. can be co-infused. Net shaping and use of peel ply can avoid grinding and post-lamination sanding.

And the hours? Placement of dry fibers is faster and the time of wetting and rolling out is eliminated. Installation of the medium and the bag takes back most of those hours. Overall, the hourly gain is usually less than 20%, but can be more if the

conversion to VIP is used as an opportunity to overhaul the complete production system. When re-usable bags or hard counter molds are part of the set-up, the gains can be more significant, but the investment is a lot higher. Infusion times are short, even for large parts: a 50-ft boat hull will typically take around 2 hours. Small parts can be infused in less than ten minutes.

....or not to VIP.

VIP may be the system of the future but it is a technology "under development". Thermosetting resin shrink during curing, and that is not about to change, it is part of the process of crosslinking. In a wet lay up this is a gradual process: every layer shrinks towards the mold surface. In VIP, all layers get wetted out and start shrinking at the same time, generating higher temperatures during curing, as all the resin in the part co-cures. In a VIP part, the complete cure cycle is completed almost instantly, contrary to traditional hand lay up where post curing and shrinkage extends over weeks, even months. This helps greatly to improve mechanical properties of the VIP part, but it also displays the final cosmetics right away.

VIP cosmetics

VIP parts have acquired the reputation of being a technician's dream and a beautician's nightmare. How good or how bad is it really?

VIP can be used for most gelcoated parts. The final surface distortion will not be much different from a hand laid part that has aged for a few months. Improving cosmetics is a field where a lot of the development will be focused in the next years. Most major resin suppliers are working on resins with lesser exothermal peeks and reduced shrinkage. But to achieve a high gloss, no-print gelcoat is not yet possible with VIP.

The EPA, MACT and HAP's: what's what

The most complete information on the new MACT legislation can be obtained from the CFA-HQ.org website and from the NMMA info services. Boatbuilders are are treated as a separate category in the new legislation. Bottom line is however that open molding as we know it will be pretty much obsolete by 2005.

INFUSION PATENTS

This is a partial list of significant infusion technology patents. Before starting to use any VIP technology, it is important to verify if the method is open, generic, or protected by a patent and subject to licensing agreements, in order to avoid patent infringement.

For more detailed patent info, cross-referencing or further research, go to: www.patents.ibm.com, or to www.getthepatent.com or to www.uspo.gov Info on patent law can be found at the www4.law.cornell.edu/uscode/35/

Significant resin infusion patents

Muskat	1950	2,495,640	Marco method
Smith	1959	2,913,036	Process and apparatus for

			molding large plastic structures
Geringer	1964	3,137,898	RTM
Muskat	1967	3,342,787	RTM
Group Lotus	1972	(GB) 1,432,333	Vacuum molding patent
Johnson	1979	4,132,755	Process for manufacturing resin-impregnated, reinforced articles without the presence of resin fumes
Rolston	1980	4,238,437	Method for producing fiber reinforced product
Fourcher	1982	4,312,829	Molding method
Palmer	1982	4,311,661	Resin impregnation process
Lecomte	1982	4,359,437	Method and apparatus for producing a thin-walled article of synthetic resin, in particular a large-sized article
Letterman	1986	4,622,091	Resin film infusion process and apparatus
Krauter	1988	4,759,893	Method of making FRP molded parts
Epel	1989	4,873044	Method and apparatus for reduction of mold cycle time
McGowen	1989	4,886,442	Vacuum bag tooling app. with inflatable seal
Seemann	1990	4,902,215	Plastic transfer molding techniques for the production of fiber reinforced plastic structures
Palmer	1990	4,942,013	Vacuum resin impregnation process
Lindgren	1990	4,975,311	Vacuum lamination station
Bailey	1995	5,588,392	Resin Transfer molding process (for boat hulls)
Seemann	1995	5,439,635	Unitary vacuum bag for forming fiber reinforced composite articles and process for

			making same
McGuiness	1996	5,526,767	Method of manufacturing a boat hull

SCRIMP™ PATENTS

Patents	Title	Inventor(s)	Issue Date
4,902,215 (US)	Plastic Transfer Molding Techniques For The Production Of Fiber Reinforced Plastic Structures	W. Seemann, III	02/20/90
5,052,906 (US)	Plastic Transfer Molding Techniques For The Production Of Fiber Reinforced Plastic Structures	W. Seemann	10/01/91
5,316,462 (US)	Unitary Vacuum Bag For Forming Fiber Reinforced Composite Articles	W. Seemann	05/31/94
5,439,635 (US)	Unitary Vacuum Bag For Forming Fiber Reinforced Composite Articles And Process For Making The Same	W. Seemann	08/08/95
5,601,852 (US)	Unitary Vacuum Bag For Forming Fiber Reinforced Composite Articles And Process For Making The Same	W. Seemann	02/11/97
5,702,663 (US)	Vacuum Bag for Forming Fiber Reinforced Composite Articles And Method For Using Same	W. Seemann	12/30/97
5,721,034 (US)	Large Composite Structures Incorporating A Resin Distribution Network	W. Seemann, III G. Tunis, III A. Perrella, R. Haraldsson W. Everitt E. Pearson	02/24/98
5,904,972 (US)	Large Composite Core Structures Formed By Vacuum Assisted Resin Transfer Molding	G. Tunis S. Winckler	05/18/99
5,958,325 (US)	Large Composite Structures And A Method For Production Of Large Composite Structures	W. Seemann E. Pearson W. Everitt R. Haraldsson A. Perella G. Tunis	09/28/99